Columbia University
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LAMONT GEOLOGICAL OBSERVATORY

PALISADES, NEW YORK

Technical Report No. 2

(Contract NObsr 43355)

Three Channel Amplifier for use in Refraction and Sound Measurements at Sea

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Three Channel Amplifier for use in Refraction and Sound Measurements at Sea

Technical Report No. 2

by

George Sutton

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ABSTRACT

A three channel amplifier for seismic investigation at sea is described. Details of design and construction are presented, including: voltage and frequency response characteristics, schematic diagrams, and a chassis layout plan. Troubles experienced in previous operation and suggested improvements are listed.

At present four of these amplifiers are being used with considerable success.

INTRODUCTION

This paper is not for the purpose of describing a completed amplifier recommended for general use at sea, but as a progress report to describe what advances have been made in developing a versatile and workable recording system.

This paper is reproduced in this form primarily to make available to the present users of the equipment a set of schematics and the frequency response of the three channel amplifier.

PURPOSE

The three channel amplifier was designed for use in seismic investigation at sea. The acoustic source is an explosion, the energy received being of three distinct types of maximum energy variations of 120 db.

The distinct arrivals are:

1. "Ground Waves" (G) - low to moderate amplitude emergent signals of low frequency (7-60 cycles/sec.);
2. "Direct Water Waves" (D) - low to high amplitude (depending on water structure and distance) impulsive signals of high frequency (1000 cycles/sec and up);
3. "Reflected Water Waves" (R) - high amplitude impulsive signals containing a broad band of frequencies, (Second and higher order reflections are sometimes of emergent character.)

In order to observe G and D simultaneously it is necessary to amplify and record their component frequencies separately. Also, a large dynamic range is required if the characteristics of the signal at all energies is to be faithfully recorded. Another factor affecting the design of a sea seismic amplifier is the low frequency (< 10 cycles/sec) noise sometimes generated by the motion of the hydrophone cable in the water.

GENERAL DESCRIPTION

In order to fulfill the above requirements, the three channel amplifier divides the signal output from a crystal hydrophone containing a Woods Hole Oceanographic Institution cathode follower pre-amp into three frequency components - high, medium, and low. Each of these components is amplified independently in a separate channel containing five outputs, one for each stage of voltage amplification. See Fig. 1 for block diagram of the amplifier. The primary purpose of the high frequency channel is to record the high frequency D while attentuating the lower frequency G and water noise. The low frequency channel is used as the main source of information about G, and, since the medium frequency channel discriminates against the low frequencies which are generated by the sea, its primary function is to check against the low frequency channel in the reading of G under noisy sea conditions.

The reason for obtaining a large dynamic range by using five output levels rather than an A.V.C. system is to make it possible to determine amplitudes directly from the reflection records.

DESIGN OF POWER OUTPUT STAGES

The power output stages are designed to drive century 220 cycle/sec. galvanometers, whose coil impedance is 20 ohms, in parallel with 20 ohm damping resistors needed for .707 critical damping. In order to protect the galvanometers from excessive signals, a limiting circuit is included in each stage. The high frequency outputs are rectified so that the envelope of the high frequency signal is recorded. This is done so that the more sensitive low frequency galvanometers may be used in place of high frequency instruments. Since, at the recording speeds used for deep sea work, frequencies above approximately 400 cycles/sec. are not identifiable, there is little loss in record character by doing this.

RESPONSE CHARACTERISTICS AND DETAILS OF CONSTRUCTION

The voltage response of the low and medium frequency channels (Fig. 2) in cm. galvanometer deflection / m.v. is constant from 1 cm. deflection to maximum readable signal. The reason for an apparent increase in gain below 1 cm. galvanometer deflection has not yet been investigated. Due to the characteristics of the output rectifier, the high frequency voltage response curve shows a gradual increase in gain to about 4 cm. galvanometer deflection. The curves of Fig. 2 are for Power output stage #4 and are representative of the other stages.

The gain per stage of the low and medium frequency channels at 10 cm. galvanometer deflection is 13, and that for the high frequency channel is 7. This is the maximum gain per stage that permits a continuous

readable record with the variations in signal amplitude encountered. The low and medium frequency channels will produce a continuous readable record with inputs ranging from $<10\,\mu$ v. ($10\,\mu$ v. = 1 cm deflection at the 4th stage) to .5 volts (.5 volts = 8 cm deflection at 1st stage). The dynamic range of the high frequency channel covers inputs from $70\,\mu$ v. (.3 cm deflection at 4th stage) to .25 volts, (8 cm. deflection at 1st stage).

The frequency response curves of the three channels are shown in Figs. 3 and 4. The half power points for the low, medium,and high frequency channels are 3.5 - 135 cycle/sec., 30-250 cycles/sec., and 620 - 14,000 cycles/sec., respectively. The upper frequency cut-off of the medium frequency channel is limited by the 220 cycle galvanometers used in the measurements.

The chassis layout plan, power connection diagram, schematic diagrams, and components list are shown in Figs. 5, 6, 7, 8, 9, and 10 respectively and are self explanatory.

SUGGESTED IMPROVEMENTS

1. Except possibly for the high frequency channel, the gain of the 5th power output stages is too high for use with the W.H.O.I. pre-amp., AX-58 crystal, and Century 220 cycle galvanometers. Also, the above mentioned pickup is capable of producing signals in excess of .5 volts. In order to record the larger signals without destroying the dynamic range, one voltage stage could be eliminated and the inputs to the power stages shifted down one stage, (i.e., Divide the voltage across

R_{10} in Figs. 7 and 8 in the ratio 1/12 and apply the resulting voltage to the first power stage, place the second power stage in place of the first, etc.).

2. The design of a quiet low impedance power supply for the high voltages would save considerable expense and the inconvenience of using two sets of batteries.

3. The use of twin triodes in the voltage stages would reduce the power requirements and amplifier background noise. Also, triodes may possibly be used in the output stages. Both 1620's and 6 S J 7's are difficult to obtain on short notice.

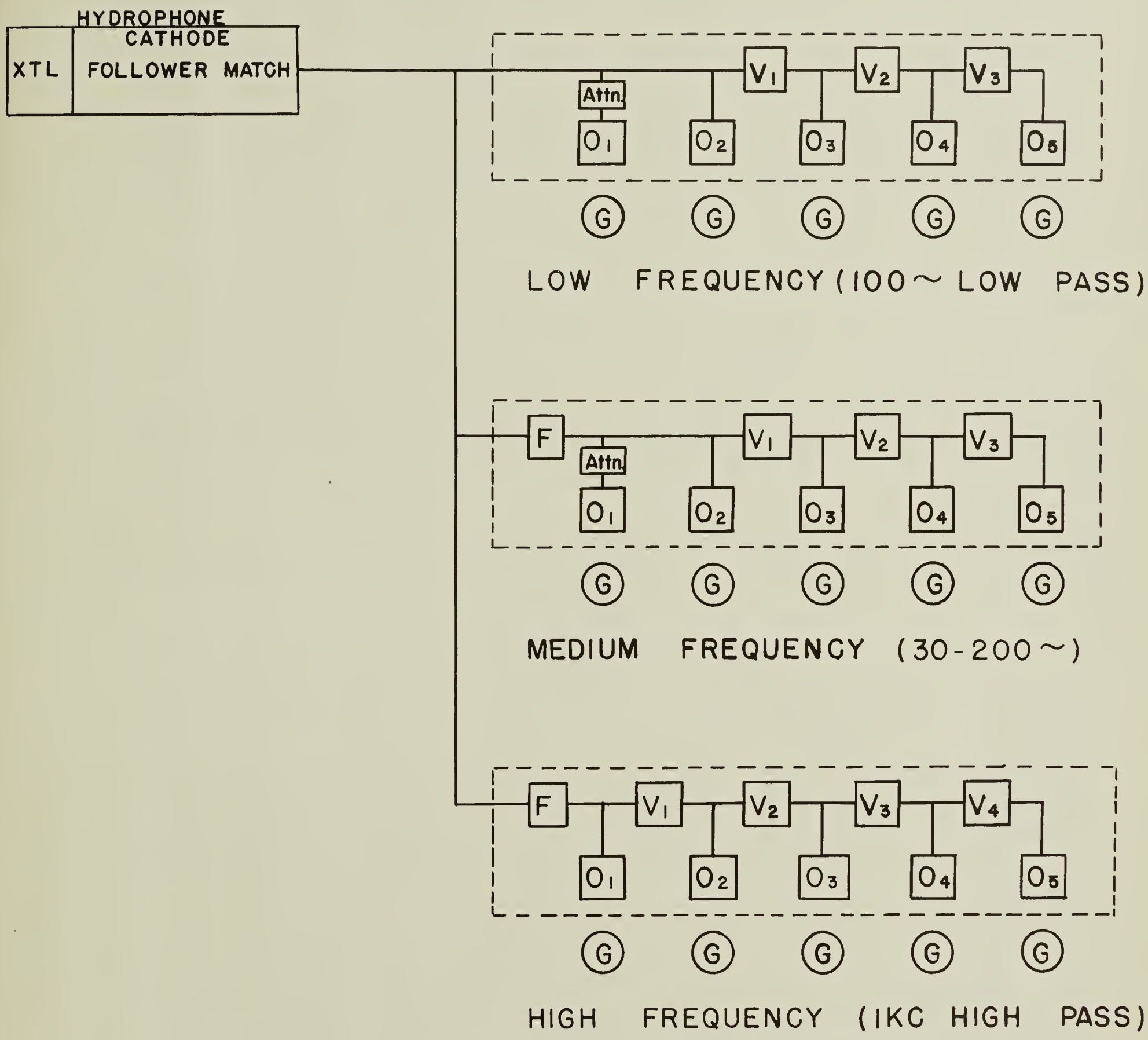
4. The incorporation of variable low pass filtering into the low frequency channel and variable high pass filtering in the medium frequency channel would greatly increase the usefulness of the amplifier under certain sea conditions.

TROUBLE EXPERIENCED IN OPERATION

Symptom	Probable Cause
1. No output beyond a certain stage.	Shorted grid cap on voltage amplifier tube (1620)
2. Excessive noise or motor-boating.	poor battery connections or low batteries
3. Distorted output.	Bad 1N34 limiting rectifiers
4. Low gain or no rectification on high frequency trace.	Bad Conant "T" rectifier, shorted or low bias battery, bad 1N34.

Fig. 1

THREE CHANNEL AMPLIFIER



Attn.— Voltage Attenuation
F — High Pass Filter
V — Voltage Amplification
O — Output Stage
G — Galvanometer

Voltage Response

O.P. Stage #4
Low @ 50
Medium @100
High @ 4KC
Century 220 Gals

Gal. Defl. (cm.)

24
22
20
18
16
14
12
10
8
6
4
2

Low
Medium
High

0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 Low & Medium
0 .2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8 2.0 High

E in (MV)

Fig. 2

Low And Medium Frquency Response Curves

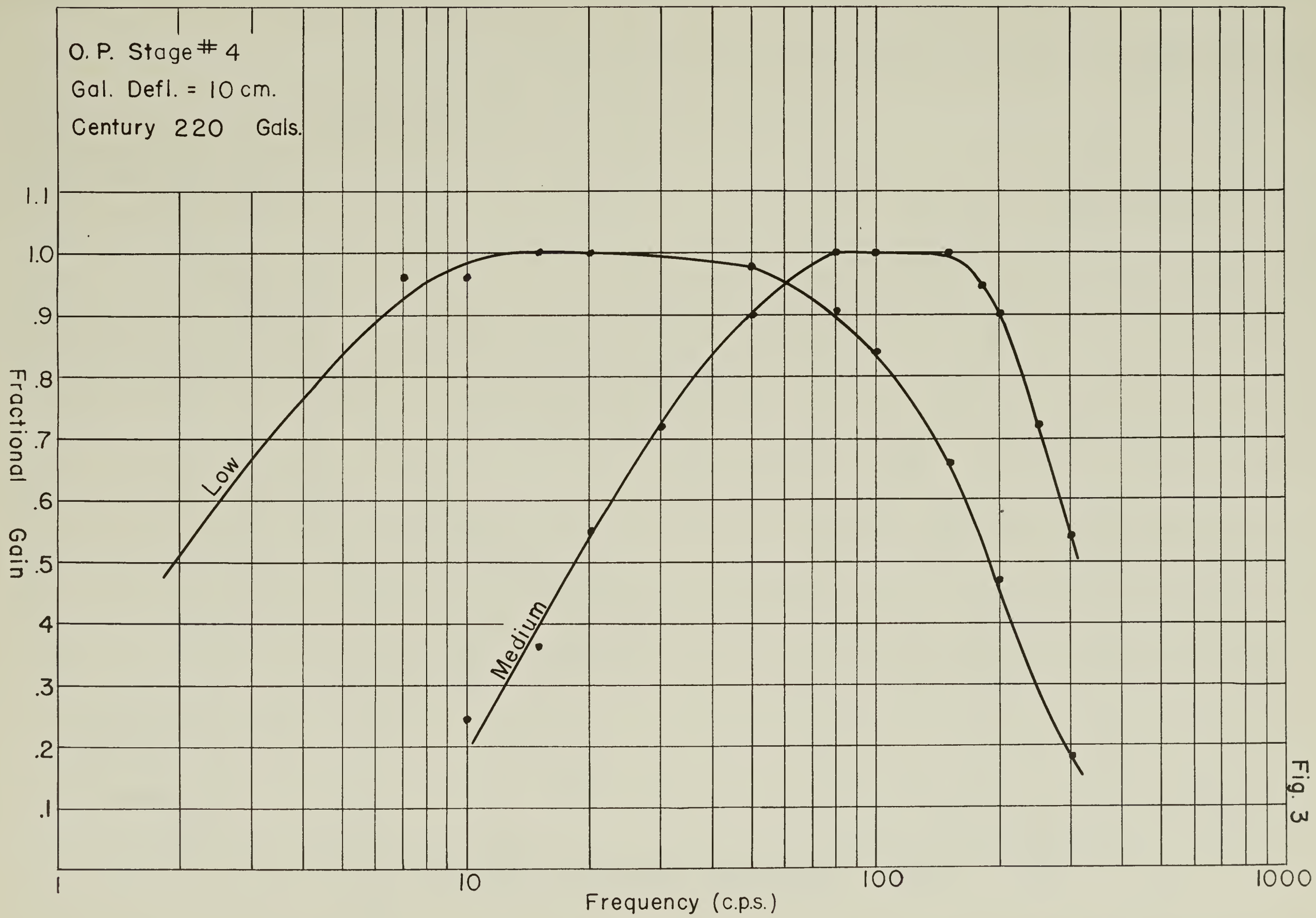


Fig. 3

High Frequency Response Curve

O.P. Stage # 4
Gal. Defl. = 10 cm.
Century 220 ~ Gals.

Fractional Gain

1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1

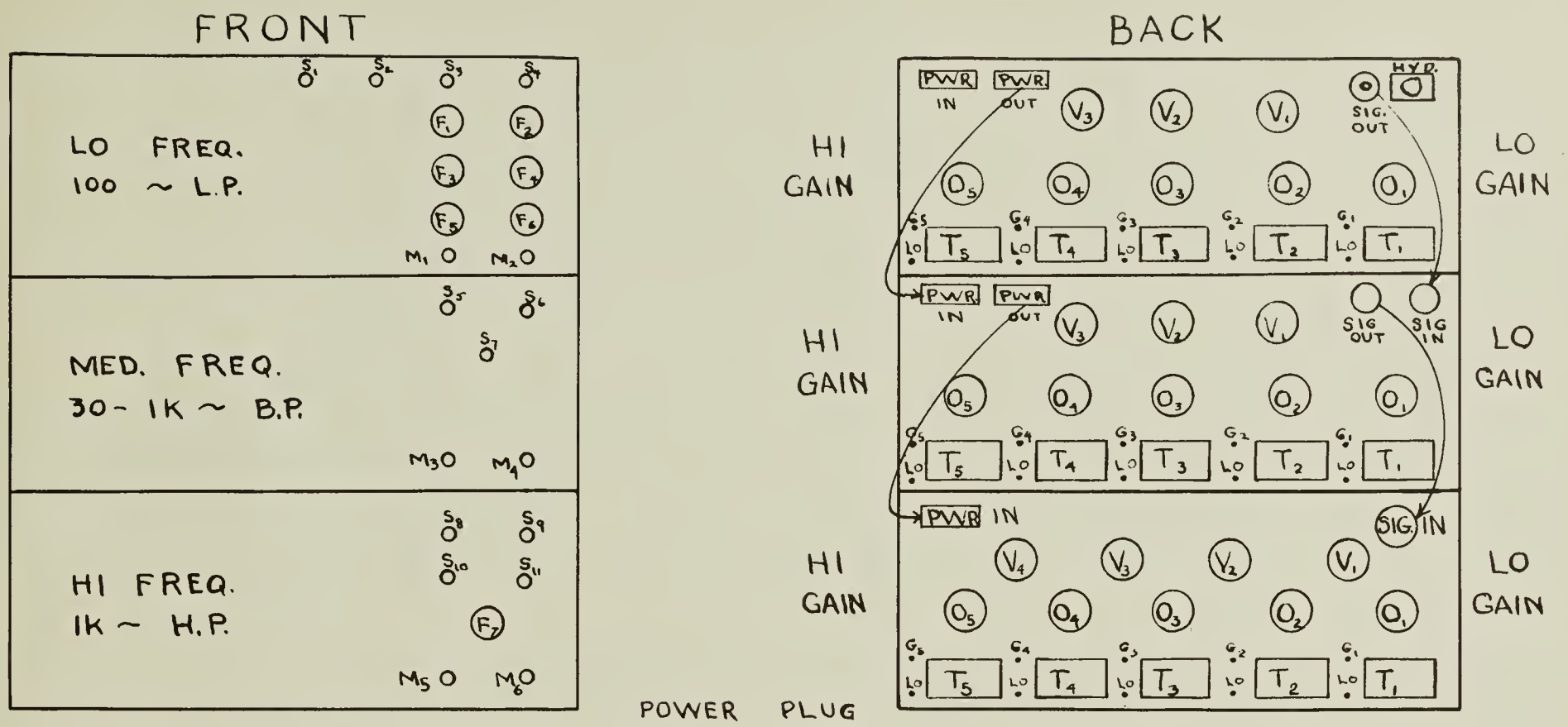
100
1000
10,000
100,000

Frequency (c.p.s.)

Fig. 4

CHASSIS LAYOUT PLAN

Fig. 5



1 + 2 - A⁻, B⁻, Sig.⁻, Chassis Ground
3- A⁺ (12V)
4- Hyd. B⁺ (90)
5- Voltage Stage G⁺ (112½V)
6- Voltage Stage B⁺ (270V)
7- Output Stage G⁺ (112½V)
8- Output Stage B⁺ (270V)
[Use Separate Batteries For Output Stage]

S_1 L.F. ~ Hydrophone A⁺ (12V)
S_2 L.F. Output Stage B⁺ + G⁺ (270 + 112½)
S_3 L.F. Voltage Stage B⁺ + G⁺ (270 + 112½)
S_4 Hydrophone B⁺ (90V)
S_5 M.F. A⁺
S_6 M.F. Voltage Stage B⁺ + G⁺
S_7 M.F. Output Stage B⁺ + G⁺
S_8 H.F. A⁺
S_9 H.F. 15V Limiters
S_{10} H.F. Voltage Stage B⁺ + G⁺
S_{11} H.F. Output Stage B⁺ + G⁺
V Voltage Stage Tubes (1620)
O Output Stage tubes (6SJ7)

F_1 A⁺ (10A)
F_2 Hyd. B⁺ (⅛A)
F_3 Output Stage B⁺ (¼A)
F_4 Voltage Stage G⁺ (¼A)
F_5 Output Stage G⁺ (⅛A)
F_6 Voltage Stage B⁺ (⅛A)
F_7 H.F. Limiter (⅛A)
M_1 L.F. Lo Gain Monitoring Output
M_2 L.F. Hi Gain " "
M_3 M.F. Lo Gain " "
M_4 M.F. Hi Gain " "
M_5 H.F. Lo Gain " "
M_6 H.F. Hi Gain " "
T Output Transformers (Lo Freq - SIE-SGO 16C), (Med. + Hi. Freq. (UTC-A24)
G Out to galvanometers (Lo terminals are grounded to chassis.)

POWER REQUIREMENTS

Voltage Stages	Output Stages
B (270v) 18ma.	B (270v) 32 ma.
G (112½ v) 4.8 ma.	G (112½ v) 10 ma.
Filaments (12v.) 4.0 Amps.	Hyd. B (90v) 2.4 ma.

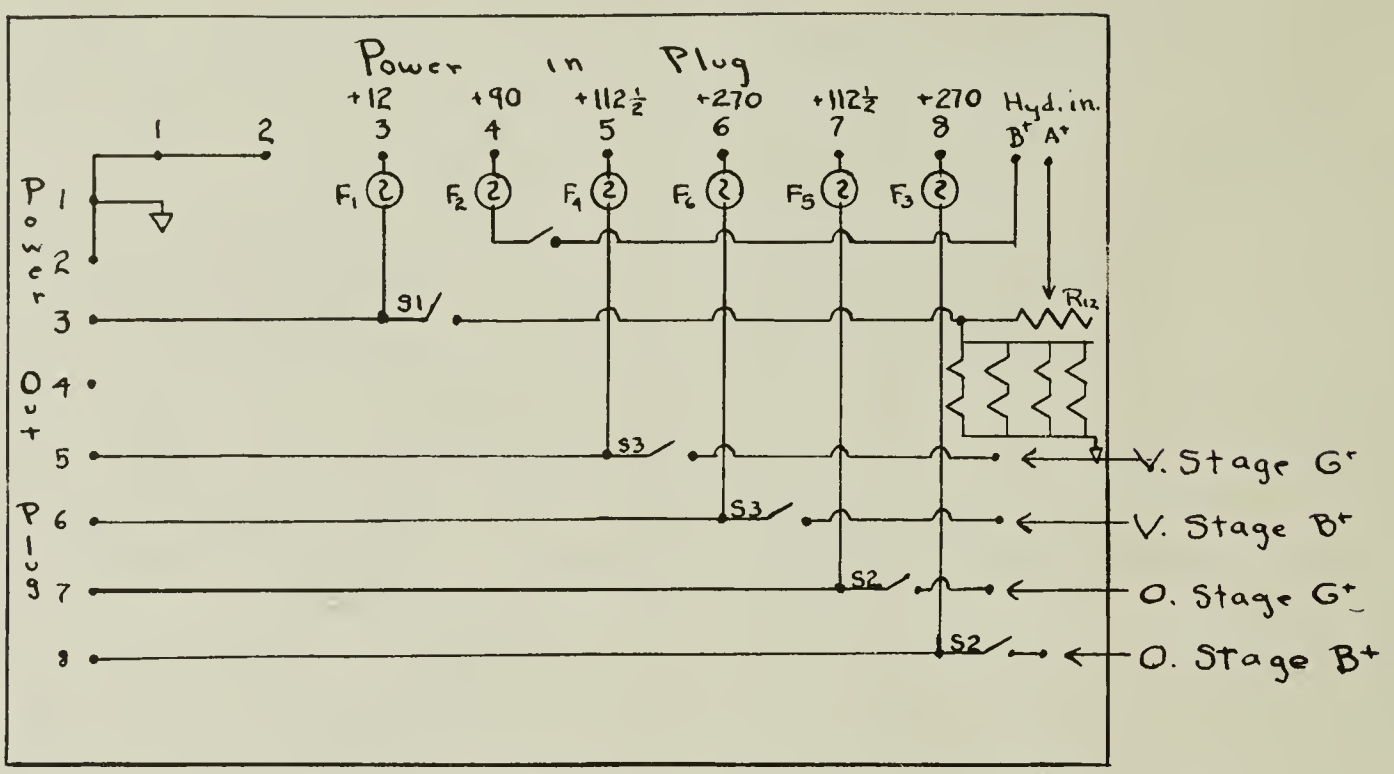
CAUTION:

IF POWER IS APPLIED TO "POWER OUT" PLUG LO FREQ. CHASSIS WILL NOT BE FUSED.

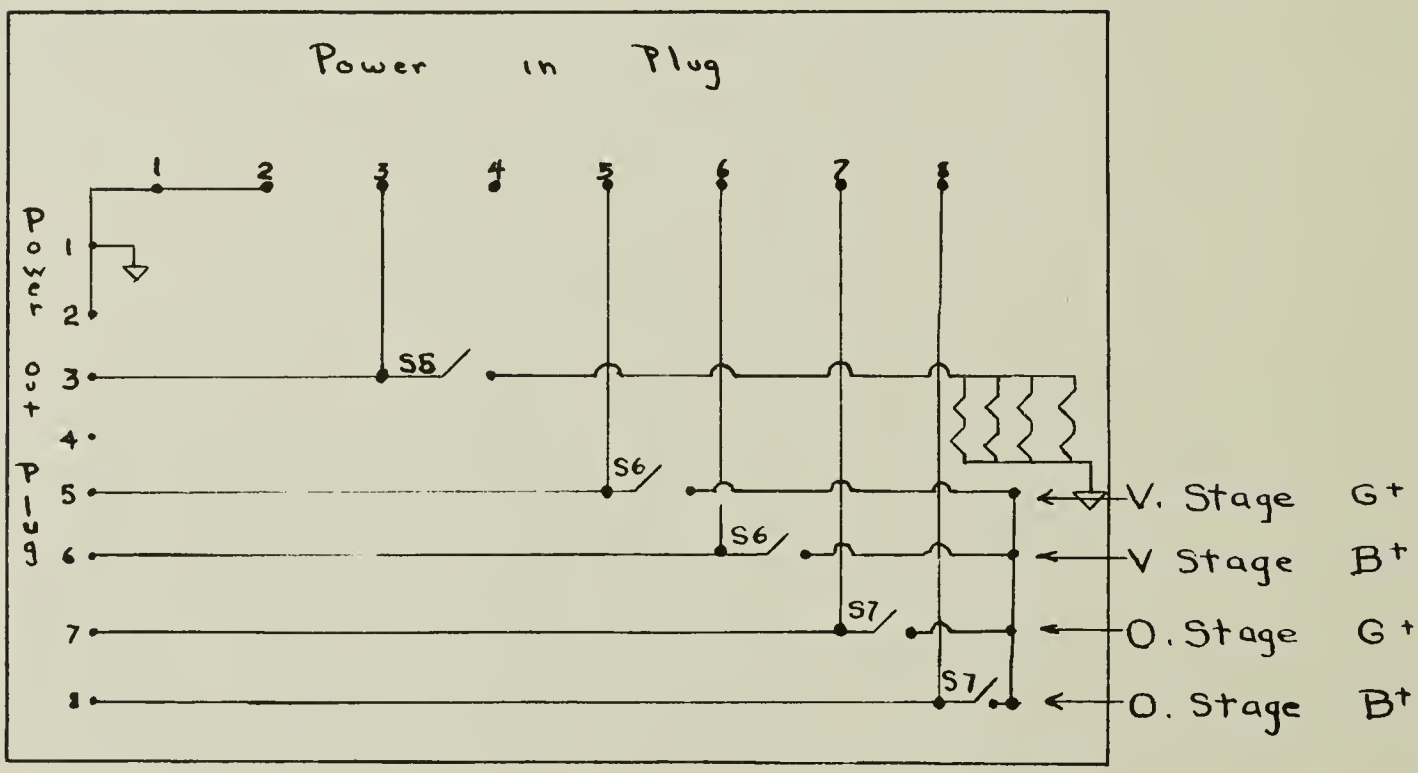
Power Connections

Fig. 6

Lo Freq. Channel



Med. Freq. Channel



Hi. Freq. Channel

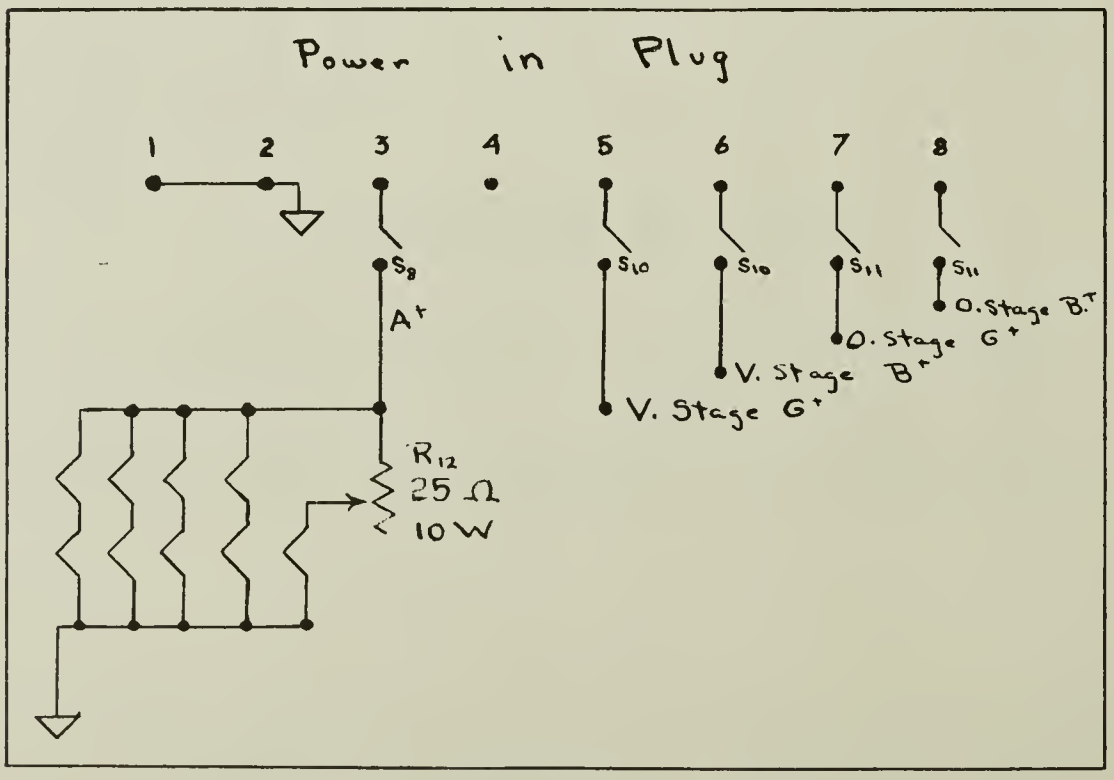
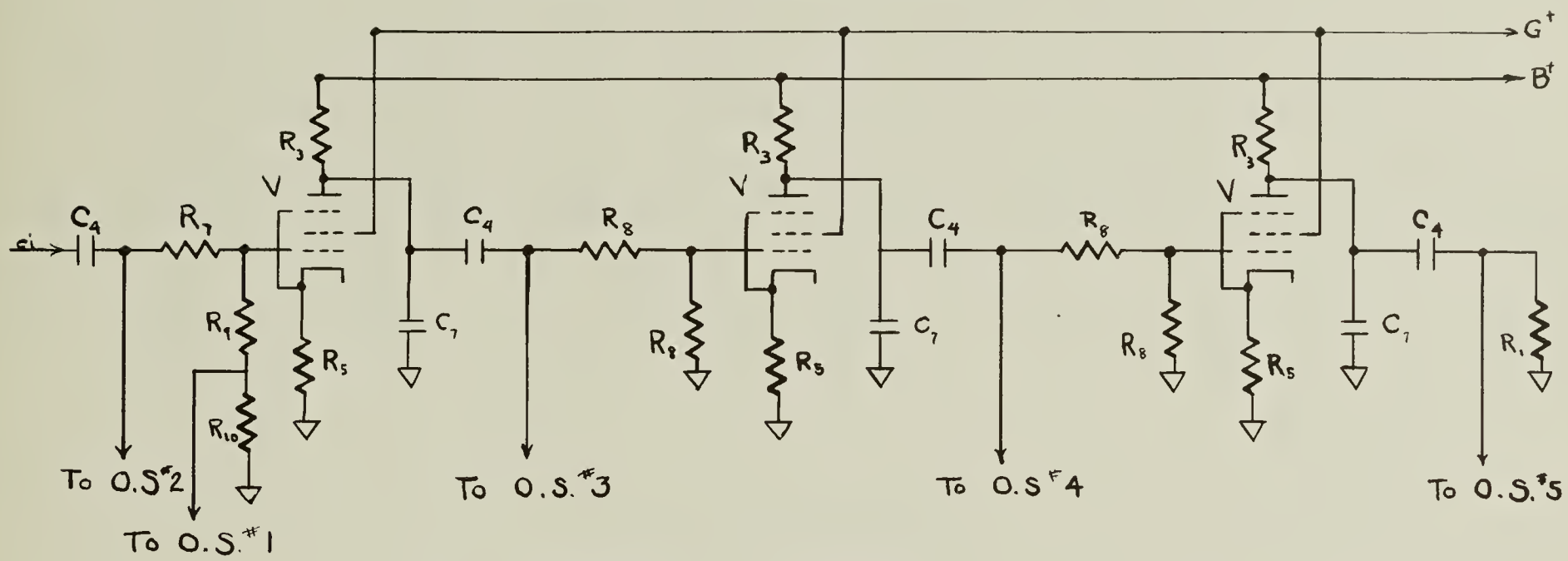


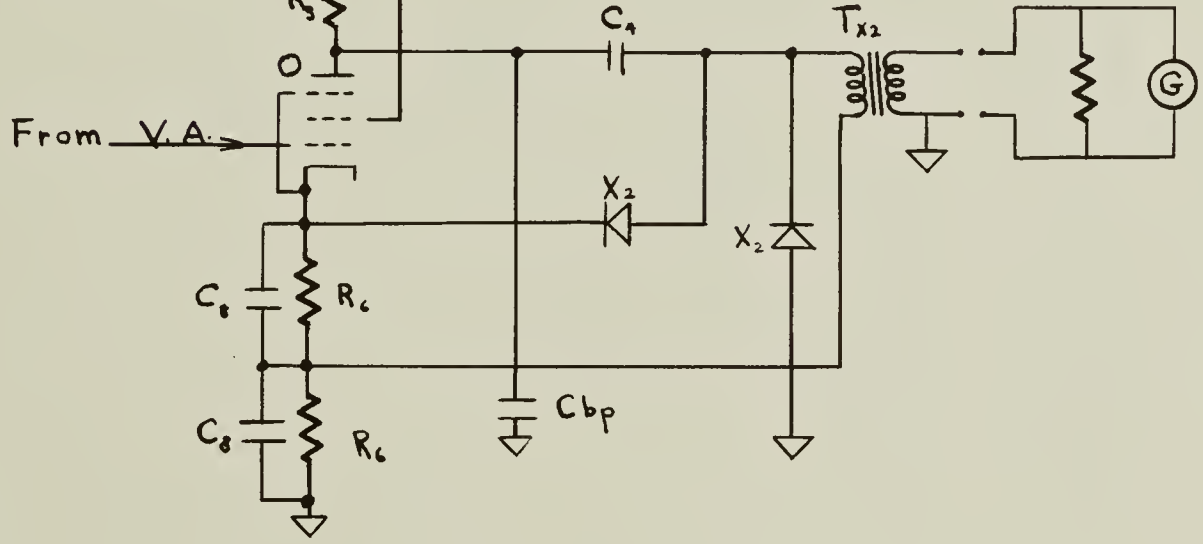
Fig.7

LOW FREQUENCY CHANNEL

VOLTAGE AMPLIFIER



OUTPUT STAGE



R_1	470	K Ω
R_3	82	K Ω
R_5	1.5	K Ω
R_6	1	K Ω
R_7	270	K Ω
R_8	240	K Ω
R_9	160	K Ω
R_{10}	39	K Ω
V	TYPE	1620
O	TYPE	6SJ7

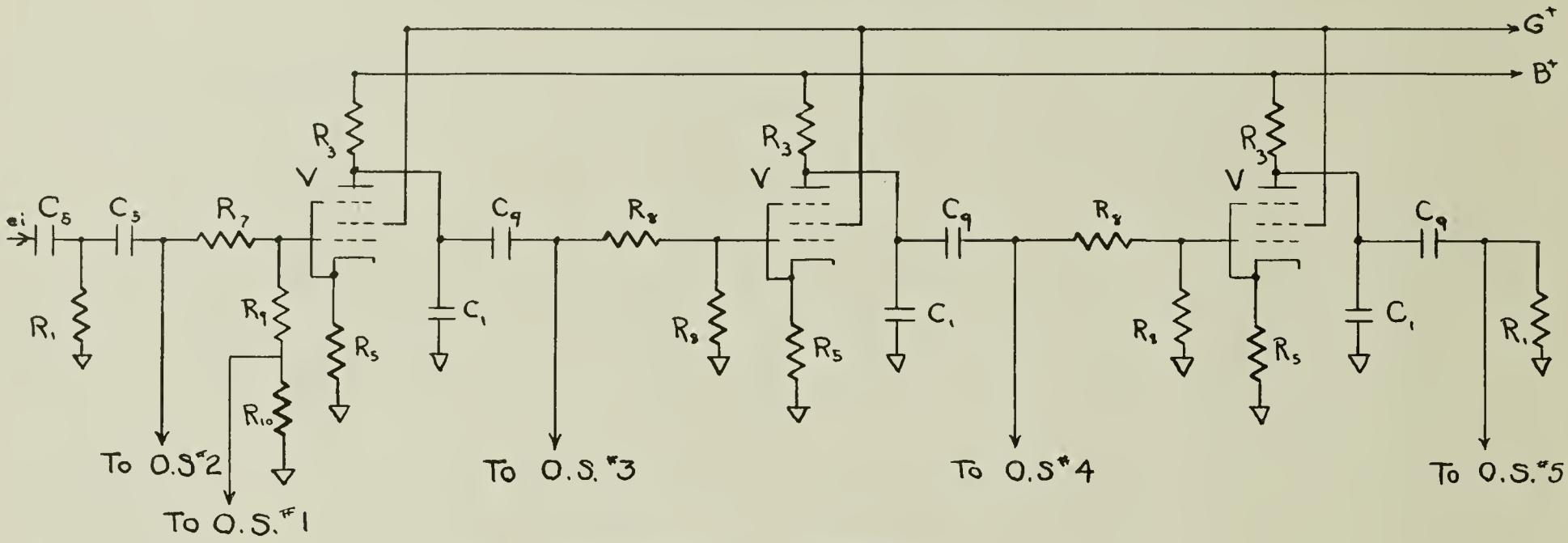
C_4	1 μf
C_7	.01 μf
C_8	500 μf
X_2	SYLVANIA IN34 OR IN34A
T_{X2}	S.I.E. S.G.O. 16C

C_{bp}	Stage
.1 μf	1st + 2nd
.05 μf	3rd
.01 μf	4th
0 μf	5th

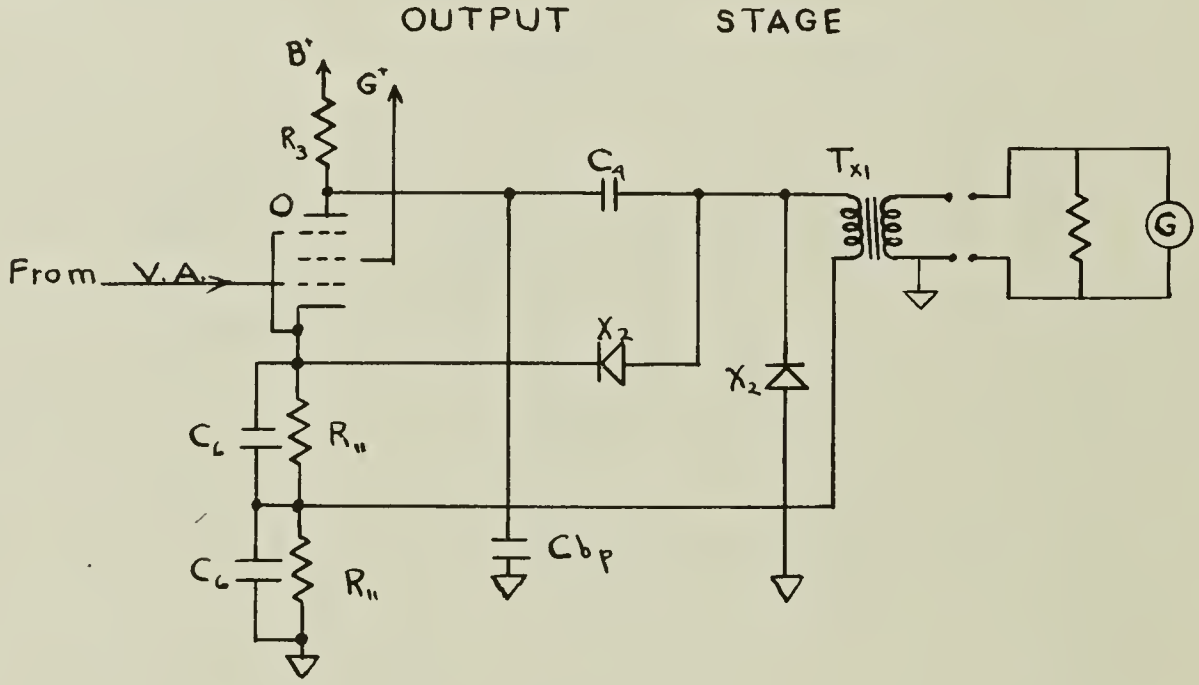
Fig. 8

MEDIUM FREQUENCY CHANNEL

VOLTAGE AMPLIFIER



OUTPUT STAGE



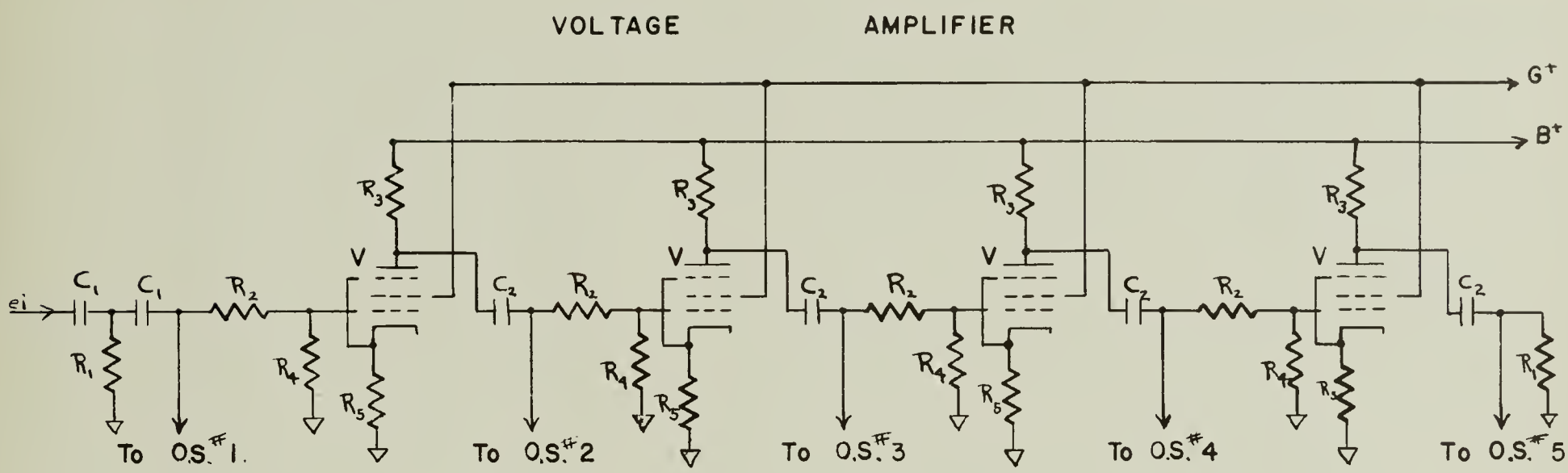
R_1	470	K Ω
R_3	82	K Ω
R_5	1.5	K Ω
R_7	270	K Ω
R_8	240	K Ω
R_9	160	K Ω
R_{10}	39	K Ω
R_{11}	560	Ω
C_1	.001	μf
C_4	1	μf
C_5	.03	μf
C_6	250	μf
C_9	.1	μf

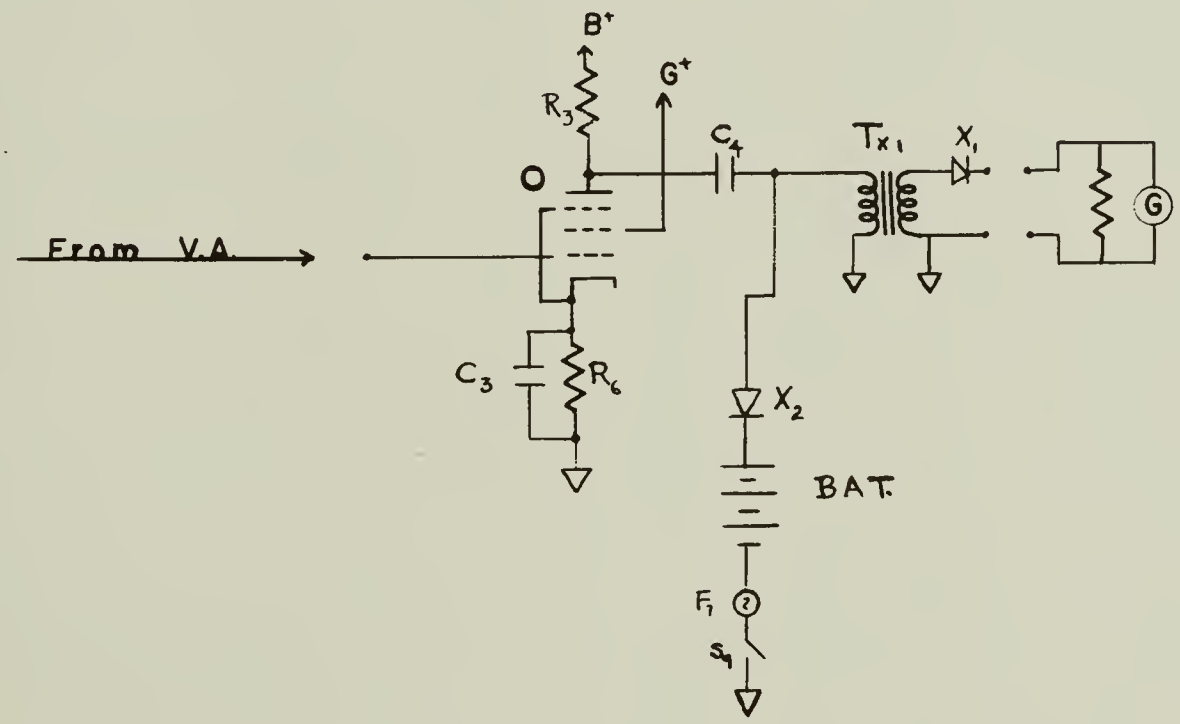
V	TYPE 1620
O	TYPE 6SJ7
X_2	SYLVANIA IN34 OR IN34A
T_{x1}	UTC A24

C_{bp}	Stage
.01 μf	1st + 2nd
.005 μf	3rd
.001 μf	4th
0 μf	5th

HIGH FREQUENCY CHANNEL

Fig. 9





R_1	470 K Ω	C_1	.001 μf
R_2	330 K Ω	C_2	.006 μf
R_3	82 K Ω	C_3	20 μf
R_4	150 K Ω	C_4	1 μf
R_5	1.5 K Ω	X_1	CONANT TYPE T
R_6	1 K Ω	X_2	SYLVANIA IN34 OR IN34A
V	TYPE 1620	BAT.	15 VOLTS
O	TYPE 6SJ7	Tx_1	U.T.C. A24

Fig. 10

COMPONENTS LIST

R_1	470 KΩ	½ W	IRC	BTS
R_2	330 KΩ	½ W	IRC	BTS
R_3	82 KΩ	1 W	IRC	BTA
R_4	150 KΩ	½ W	IRC	BTS
R_5	1.5 KΩ	1 W	IRC	BTA
R_6	1 KΩ	1 W	IRC	BTA
R_7	270 KΩ	½ W	IRC	BTS
R_8	240 KΩ	½ W	IRC	BTS
R_9	160 KΩ	½ W	IRC	BTS
R_{10}	39 KΩ	½ W	IRC	BTS
R_{11}	560 Ω	1 W	IRC	BTA
R_{12}	25 Ω	10 W	Ohmite dividohm #1009	
C_1 & Cbp	.001 µf	C-D	PTE	6D1
C_2	.006 µf	C-D	PTE	6D6
C_3	20 µf	C-D	BR	202 A (25 V DC)
C_4 & Cbp	1 µf		Aeroyox Aerolite Type 82 (400 W V DC) or (Tobe Metalized Type TK)	
C_5	.03 µf	C-D	PTE	6S3
C_6	250 µf	C-D	BRH	6025 (6V DC.)
C7 & Cbp	.01 µf	C-D	PTE	4S15
C8	500 µf	C-D	BRH	605A (6V.DC.)
C_9	.1 µf	C-D	PTE	4P1
Cbp	.005 µf	C-D	PTE	6D5
Cbp	.05 µf	C-D	PTE	4S5
V	Type 1620			
O	Type 6SJ7			
Tx_1	UTC A24			
Tx_2	S.I.E. SGO 16C			
X_1	Conant Type T			
X_2	Sylvania IN 34 or IN 34A			
Bat.	15 Volts Eveready 411 or Burgess UIOE			

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